LBNL- 1006327

Minimum Energy Efficiency Standards and Appliances:
Old and New Economic Rationales

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September 2016

This is the preprint version of a paper published in *Economics of Energy & Environmental Policy*. The published version of the article can be found here: http://dx.doi.org/10.5547/2160-5890.5.2.shou

Please cite as:

Houde, S., & Spurlock, C. A. (2016). Minimum Energy Efficiency Standards for Appliances: Old and New Economic Rationales. *Economics of Energy & Environmental Policy*, *5*(2).

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State, and Community Programs, of the U.S. Department of Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH1131.

Disclaimer

Acknowledgements

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State, and Community Programs, of the U.S. Department of Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH1131.

The authors would like to thank Catherine Wolfram, Louis-Gaëtan Giraudet, Larry Dale, and Louis-Benoit Desroches for comments and suggestions. While this version is prior to the review by Paul Joskow, the final published version benefited from his valuable input, and the authors would like to thank him for those comments, and for including our work in the Symposium on Energy Efficiency collection.

Abstract

We revisit Hausman and Joskow (1982)'s economic rationales for appliance minimum energy efficiency standards. In addition to the four market failures they argued could justify appliance standards--energy prices below marginal social cost, consumers underestimating energy prices, consumer discount rates above social discount rates, or principal agent problems--we discuss two additional market failures that are relevant and potentially economically important in this context: market power and innovation market failures. We highlight puzzles uncovered by recent empirical results, and suggest directions future research should take to better understand the normative implications of appliance standards.

1. Introduction

At the time that minimum energy efficiency standards for appliances were first introduced in the U.S., Hausman and Joskow (1982) outlined what they viewed to be the main economic rationales for appliance standards. In this article, we revisit Hausman and Joskow (1982) and provide further insight and new discussion regarding the four market failures they highlight as justifications for standards: energy prices below social marginal cost, consumers underestimating energy prices, consumer discount rates above social discount rates, or principal agent problems. We then discuss two additional market failures: market power and innovation market failures. While many others have discussed these market failures in the context of energy efficiency policy generally (e.g., Fischer 2004; Gillingham, Newell, and Palmer 2004, 2006; Allcott and Greenstone 2012; Gerarden, Newell, and Stavins 2015), we feel that they deserve further emphasis in the context of the appliance market in light of recent empirical evidence.[1] Recent work suggests that the behaviors of firms operating in the appliance market make a particularly interesting case for minimum standards.

A focus on consumer rationality and consumer choice has held through much of the discourse surrounding economic justifications for standards. Some have argued that bounded rationality, information asymmetries, and the seemingly high discount rates that consumers apply to the appliance purchasing decision, a phenomenon broadly defined as the Energy Efficiency Gap (Jaffe and Stavins 1994a) are justifications for standards (e.g., Howarth and Sanstad 1995; Levine, Hirst, Koomey, McMahon, and Sanstad 1994). Others have argued that consumers are in fact making choices that are rational and do maximize their private benefits, and that standards restrict the choice set offered to consumers and must therefore negatively impact consumer welfare (e.g., Gayer and Viscusi 2013). Although this debate is still unresolved and relevant, we believe that it is time to broaden the conversation to include economic agents on the supply side of these markets. The actions of manufacturers and retailers might ultimately impact the welfare outcomes of standards to a greater extent than do consumer behaviors and preferences alone. The very nature of the choice set faced by consumers has an important role in the choices consumers make, and may well be strategically designed to take advantage of information asymmetries or play off of cognitive (e.g., bounded rationality) or systemic (e.g., split-incentive) biases present in the market. We believe that market failures in the supply side of the market, and their potential interconnection with imperfect information or bounded rationality of consumers, have important implications for regulation that has been under-emphasized in the literature to this point.

This shift of perspective is motivated by recent empirical findings, which we will outline in this article. Some of these findings bring to light a puzzle. Specifically, appliance prices have followed downward trends and the introduction and revision of standards appear to accentuate these trends. Simultaneously, the quality of appliances has been increasing over time, including over periods of

[1] While some of the insights we discuss may be relevant in other settings, the scope of this article is limited to a discussion of the appliance market, particularly in the U.S.

increasingly stringent standards, even in dimensions outside energy efficiency. We will discuss these results, as well as the future research we believe is needed to get to the root of this puzzle and to better understand the normative implications of minimum energy efficiency standards.

2. U.S. Appliance Minimum Energy Efficiency Standard Policy

Federal minimum energy efficiency standards for appliances in the U.S. were first established in the Energy Policy and Conservation Act (EPCA, Pub. L. No. 94-163) of 1975.[2] EPCA included a number of energy policy elements, including the establishment of standards for automobiles, test procedures, energy labeling (eventually resulting in the yellow EnergyGuide labels seen on products today), and standards for appliances with a target to improve efficiency of covered products by 20 percent above 1972 levels. There were thirteen appliance product groups covered by EPCA 1975,[3] but the Department of Energy (DOE) Building Technologies Office now covers, according to their website[4], more than sixty categories of appliances and equipment under this program, and claims that "products covered by standards represent about 90% of home energy use, 60% of commercial building use, and 30% of industrial energy use."

The impetus for these initial set of energy efficiency regulations was a combination of the efforts of California, which established their own set of minimum standards in 1977, concerns about energy security following blackouts in the Northeast in 1965, and impacts on consumer energy consumption expenditure. In particular, EPCA 1975 states its purpose to be: "To increase domestic energy supplies and availability; to restrain energy demand; to prepare for energy emergencies; and for other purposes," and calls for the establishment of a standard in such cases where the labeling provision "is not likely to be sufficient to induce manufacturers to produce, and consumers and other persons to purchase, covered products of such type (or class thereof) which achieve the maximum energy efficiency which it is technologically feasible to attain, and which is economically justified."

[2] EPCA 1975 was amended in 1978 by the National Energy Conservation Policy Act (NECPA, Pub. L. No. 95-619), various components of which ended up delaying the establishment of standards. Minimum energy efficiency standards for appliances were finally enacted through the National Appliance Energy Conservation Act (NAECA, Pub. L. No. 100-12), of 1987, which established standards that started coming into effect on January 1st, 1988.

[3] The initial set of covered appliances were: refrigerators and refrigerator-freezers, freezers, dishwashers, clothes dryers, water heaters, room air conditioners, home heating equipment not including furnaces, television sets, kitchen ranges and ovens, clothes washers, humidifiers and dehumidifiers, central air conditioners, and furnaces.

[4] http://energy.gov/eere/buildings/appliance-and-equipment-standards-program

3. Revisiting Hausman and Joskow (1982)

At the time that the first generation of minimum energy efficiency standards for appliances were enacted, Hausman and Joskow (1982) identified four market failures that could potentially justify such regulation: (i) energy prices below social marginal cost; (ii) consumers' underestimation of future energy prices; (iii) consumers applying too high of discount rates in the appliance purchasing decision relative to the social discount rate; and (iv) principal-agent problems where the party investing in energy saving technologies may not be responsible for paying energy bills. We review these four market failures and update the discussion surrounding them with recent empirical evidence.

3.1. Energy Prices Below Social Marginal Costs

Unpriced externalities and distortions induced by various regulations may result in retail energy prices that are too low compared to the social optimum. For electricity and natural gas prices, there are broadly three types of externalities that should be accounted for: local air pollution, carbon-related damages, and energy security externalities. Long gone is the energy crisis of the 1970s. In the current U.S. context where most of the fossil fuels (e.g., coal and natural gas) for U.S. electricity generation do not come from imports, the economic importance of energy security externalities may be negligible (Metcalf 2014).

For local air pollution and carbon damages, there is some agreement that the combined cost of these two externalities in the U.S. may range from 9 to 12 cents per kilowatt-hour (kWh) for coal-fired power plants (Gerarden, Newell, and Stavins 2015), and may be less than 2 to 3 cents per kWh for natural gas power plants.[5] Considering that the average U.S. electricity price is about 11 cents per KWh, these externalities are sizable. However, given that there are currently several environmental regulations targeting local air pollution associated with electricity generation, this externality is partly accounted for in current electricity prices. However, even if local air pollution was fully internalized, electricity and natural gas prices might still be too low because carbon damages are yet to be systematically accounted for everywhere in the U.S.

The role of regulation in both the electricity and natural gas sectors, however, complicates the matter. In particular, rate-of-return regulation may lead to energy prices that are too high when utilities recover fixed costs by charging prices above marginal costs. Davis and Muehlegger (2010) show that this distortion is economically important in the U.S. natural gas market and amounts to a carbon price of about $50 a ton of CO_2. Older work by Naughton (1986) also suggests that rate-of-return regulation may have a similar effect in the electricity sector.

In sum, unlike in the context of the 1970s energy crisis, when U.S. subsidized energy prices were clearly below market prices, current regulatory distortions may have the opposite effect and could even

[5] These estimates represent national averages and do not account for substantial spatial heterogeneity in the damages related to local air pollution (Muller and Mendelsohn 2009).

counterbalance as yet unpriced externalities. Therefore, whether today's energy prices are below social marginal costs and hence remain a valid economic rationale for appliance minimum energy efficiency standards is unclear.

3.2. Consumer Underestimation of Energy Prices

At the time that Hausman and Joskow (1982) wrote their review, they concluded that almost no work had been done to study how consumers form expectations about future energy prices, with the exception of Daly and Mayor (1983). More than thirty years later, this area of research is still relatively unexplored, especially when it pertains to electricity and natural gas prices. More work has been done in the context of gasoline prices; Allcott (2011) and Anderson, Kellogg, and Sallee (2013) are two such important studies, both of which conclude that consumers tend to rely on current gasoline prices as their best forecast of future gasoline prices. Given that historically the best predictor of gasoline prices has tended to be a random walk (Hamilton 2009), consumers' "no-change" forecast has then been consistent with rational expectations. The current consensus is that consumers' expectations about gasoline prices are not systematically biased and therefore not a strong rationale for Corporate Average Fuel Economy (CAFE) standards.

It is unclear if the conclusions of these studies for the U.S. vehicle passenger market translate well to the appliance market. However, if consumers do rely on a "no change" forecast, as they do in the gasoline price setting, then expectations about future electricity prices should have a rather limited role in motivating appliance standards, at least in the U.S., given that electricity prices have become more stable in recent years. For instance, Figure 1 presents a three-year moving average of the annual percent change in the average real U.S. electricity price. During the 1990-2012 period, the average change has remained stable and ranged from -1 to -2%. This contrasts with the period 1970-1990 when electricity prices were much more volatile. In sum, the size of the deadweight loss due to consumers relying on a "no change" forecast of electricity prices should be small in the current environment where prices have had little variation over time.

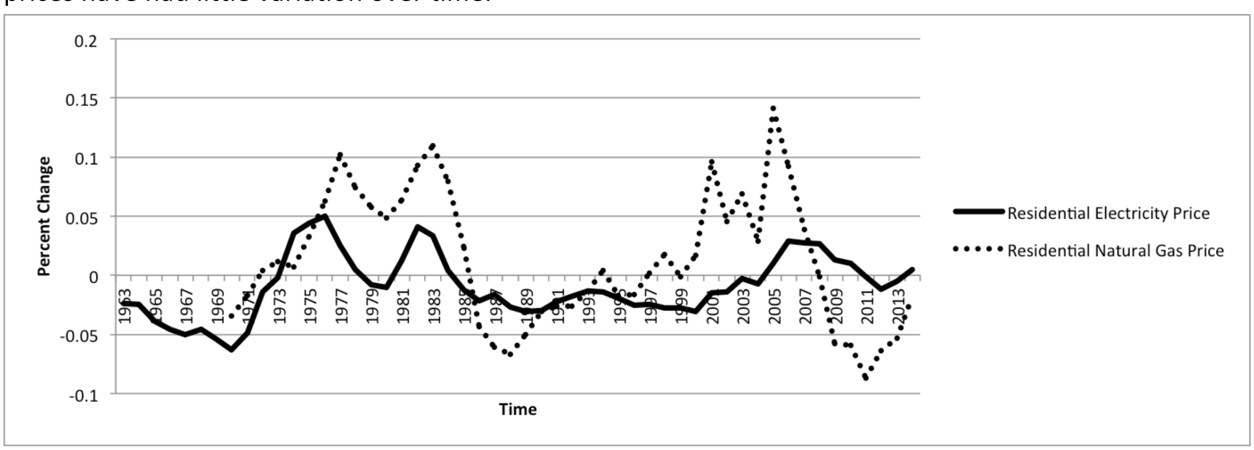

Figure 1. Rate of Change of Energy Prices over Time

Note: three year moving average of the annual percent change in energy prices. Data was from the EIA Annual Energy Review 8.10 Average retail prices of electricity, 1960-2014, and 6.8 Natural gas prices by sector, 1967-2014. All prices were deflated using the CPI from the BLS.

For natural gas, there may be a different story. The recent technological advances in oil and gas extraction, and the resulting boom in natural gas, has had a noticeable effect on prices. Starting in 2007, we observe the largest decrease in average U.S. natural gas price over the last forty years (see Figure 1). If consumers did not forecast this decrease, the concern is that they may have been overestimating natural gas prices. As a result, consumers may have over-invested in energy efficiency for gas-using appliances and the presence of appliance minimum energy efficiency standards may have further exacerbated this problem.

A related but different question is the extent to which consumers may have biased expectations about the energy use of different types of appliances. Here, the work of Attari, Krantz, and Weber (2014) is particularly relevant as it suggests that consumers may tend to underestimate energy use of large appliances, but overestimate the energy use of smaller ones. The nature of the bias in beliefs about energy use would then motivate standards for larger appliances, but would support the opposite argument for appliance categories that are less energy-intensive. It also implies that given that gas-using appliances tend to be larger ones (e.g., heating equipment, clothes dryers, ovens), the bias in consumers' expectations of total energy operating costs caused by the possible overestimation of natural gas prices could be counterbalanced by the underestimation of energy use.

In sum, the question of whether consumers underestimate energy prices or, equally importantly for policy, overestimate appliance energy use, is still somewhat unresolved, with empirical evidence providing mixed conclusions. It appears to depend on the energy source (natural gas versus electricity) and the appliance type.

3.3. Consumer Discount Rates Above Social Discount Rates

The seminal work of Hausman (1979) showed that consumers appear to use discount rates that are higher than normal market returns for discounting the stream of future energy costs when purchasing air conditioners. There have been a large number of subsequent studies investigating this question; Train (1985) provided an early review showing that implicit discount rates, (i.e., discount rates that rationalize the trade-off between future energy costs and purchase prices), vary widely across different categories of energy intensive durables, but tend to largely exceed normal market returns. This empirical phenomenon has given rise to the concept of the Energy Paradox (Jaffe and Stavins 1994b), also referred to as the Energy Efficiency Gap (Jaffe and Stavins 1994a). As of today, it is still debated whether these high implicit discount rates are truly a characterization of consumer preferences--reflecting bounded rationality, imperfect information (e.g., Davis and Metcalf 2014) or credit constraints--or are an artifact of the econometric methods used in their estimation.

The first generation of studies estimating consumers' implicit discount rates for energy intensive durables focused on integrating usage and purchase decisions into a single estimation framework using a discrete-continuous choice model (e.g., Hausman 1979; Dubin and McFadden 1984). These studies relied on cross-sectional variation in energy prices and controlled for a small number of product attributes. As a result, these studies did not account for unobserved product attributes and region-specific demand characteristics. Both of these omissions could lead to an overestimation of implicit discount rates if more energy efficient products tend to be systematically inferior along certain dimensions, or people living in regions subject to higher energy prices tend be more credit constrained, for instance.

The bulk of the more recent studies that have used the discrete-continuous framework were conducted in the passenger vehicle market. West (2004), Small and Van Dender (2007), Bento, Goulder, Jacobsen, and von Haefen (2009), Jacobsen (2013), and Gillingham (2013) are studies focusing on the U.S. market, all of which estimate demand using a subset of car characteristics, and do not use instrumental variables. Rapson (2014) is one of the few examples of a recent study using the discrete-continuous framework applied to the appliance market (specifically air conditioners). In addition, his methodology explicitly allows for uncertainty about the future of key product attributes, models the decision to purchase at all or delay (rather than the choice made once the decision to purchase is fixed), and the intensive margin of the purchase decision (i.e., whether to purchase a central or room air conditioner). All of these facets allow his model to be closer to a realistic decision scenario compared to some related work. He found that consumers do respond to future energy costs, and in particular, that the model assuming rational expectations of consumers fits the data better than assuming highly myopic consumers or consumers with naive expectations.

There are two general empirical challenges for accounting for unobserved product attributes in the estimation of implicit discount rates: lack of rich panel data and the use of instruments in a non-linear framework. For the vehicle passenger market, recent studies that exploit panel data found no or modest evidence of consumers' undervaluation of fuel economy (Li, Timmins, and von Haefen 2009; Busse, Knittel, and Zettelmeyer 2013; Allcott and Wozny 2014; Klier and Linn 2010). Similar studies in the appliance market are scarce, but three are of particular importance. First, Houde (2014) uses a discrete choice framework and focuses on the U.S. refrigerator market. Using panel micro-level data, he controls for time-invariant attributes with product fixed effects and exploits cross-sectional variation in electricity prices across the U.S. to estimate how consumers respond to energy costs. Demographic information is used to control for region-specific characteristics. He finds large implicit discount rates, especially for lower income households. He then shows that these large implicit discount rates are driven by a fraction of the population that appear to forgo all energy information in their decision process. On the other hand, he shows that there is another fraction of the population that appears to trade off energy costs with purchase price in a way that suggests close to normal discount rates. Second, in another study focusing on the U.S. appliance market, Jacobsen (2015) uses a panel approach to show how ENERGY STAR market shares respond to variation in electricity prices. Using state fixed effects to control for region-specific unobservables, he finds that temporal variation in average state electricity prices has little or no effect on ENERGY STAR market shares. While this study does suggest very high implicit discount rates, one caveat here is that consumers may value ENERGY STAR for reasons beyond energy savings (Houde 2014; Newell, Siikam, et al. 2014). The third study is Cohen, Glachant, and Söderberg (2015), which uses a panel dataset of the United Kingdom (U.K.) refrigerator market. Their framework is similar to Allcott and Wozny (2014) and, like Jacobsen (2015), exploits temporal variation in electricity prices. An important difference in this study compared to the others is the extent to which U.K. electricity prices vary over time. During the period of their sample (2002-2007), they observe almost a doubling of electricity prices. This large increase in electricity prices contrasts with the U.S. context, which tended to have more stable electricity prices during the study periods of to Allcott and Wozny (2014) and Jacobsen (2015).[6] This provides a much stronger source of variation for estimating implicit discount rates. For their preferred estimator, Cohen, Glachant, and Söderberg (2015) find a rather modest level of undervaluation of energy costs, which translates to an implicit discount rate of about 11%. One element that is also interesting from the context of Cohen, Glachant, and Söderberg (2015) is that U.K. energy labels for refrigerators are different from U.S. labels. This could also explain the difference from the U.S. market-derived estimates.[7]

In sum, some of the more recent literature exploring this aspect of consumer preferences and decision making in the appliance setting suggests that discount rates are likely closer to the market rate of return than those that were estimated in the initial round of papers from the 1970s and 1980s. However, the variation in estimates reflects a persistent puzzle. Some have argued that variation in energy prices (and therefore anticipated returns from efficiency) tend to have little impact on appliance choice (e.g., Jacobsen 2015); others have argued that most consumers fully integrate energy operating costs in their decision (Cohen, Glachant, and Söderberg 2015), and some others have found that only a fraction of consumers respond to energy costs (Houde 2014). The ideal study should rely on a single unifying framework that allows for the comparison of estimates across appliance categories, exploits credible variation in energy prices, and accounts for market specific unobservables. Moreover, heterogeneity in implicit discount rates among different consumer segments should also be elicited, a topic that has received surprisingly little attention in the academic research until recently. This concept of heterogeneity in implicit discount rates is particularly relevant when taking into account another market failure: principal-agent problems.

3.4. Principal-Agent Problems

Principal-agent problems are an often-cited explanation for the Energy Efficiency Gap. They can motivate minimum energy efficiency standards for appliances when the principal purchasing the appliance is not responsible for utilization decisions and paying energy bills. In such a case, the principal has no incentive to consider future energy costs in its appliance purchasing decision. The rental housing market wherein landlords offer partially furnished units but require the renters to pay the energy bills may be prone to such a split-incentive problem. Hausman and Joskow (1982) discuss this market failure only briefly, as a potential explanation for evidence of high implicit discount rates, and point out that

[6] U.K. electricity generation depends largely on oil, which explains why electricity prices are much more variable in this market.

[7] In the U.K., appliances are ranked on a letter scale (A to G), and the label provides an energy efficiency ranking along this discrete scale. In the U.S., appliances may have two different energy labels. The mandatory EnergyGuide label shows the annual operating cost and a comparison of this cost with other products in the same appliance class. In addition, there is the voluntary ENERGY STAR label, a binary indicator of the most energy efficient products within a product class.

the design decisions or appliance installations made by homebuilders can also have this effect.

In the rental market, one can argue that there is a market failure only if energy efficient technologies are not capitalized into the rental price. In practice, this is likely to be the case. In the absence of detailed and credible information on the technologies installed in a unit, landlords have a limited ability to set rental prices that are strongly linked to energy bills. A few recent studies provide evidence that this problem is present and could be economically important. Davis (2011) finds that U.S. renters are significantly less likely to own ENERGY STAR refrigerators, clothes washers, and dishwashers compared to homeowners. Gillingham, Harding, Rapson, et al. (2012), focusing on California alone, find that owners that occupy their units and pay for their energy bill are significantly more likely to insulate their units relative to owners that do not pay for energy bills. Myers (2015) finds similar results focusing on the northeastern U.S. with regard to heating decisions: landlords that pay for their energy bills are more likely to invest in more energy efficient heating units. She also finds evidence that there is substantial information asymmetry between landlords and tenants, such that energy costs are not completely capitalized into rents and renters do not fully anticipate energy costs of their units. Her policy simulations suggest that removing information asymmetries in this particular context would reduce energy use by 1-3%.

We are not aware of a study that directly compares minimum standards to energy labeling policies in order to address this asymmetric information problem stemming from the split-incentive market failure, especially in the building sector. This is partially due to the lack of labeling and information disclosure policies targeting building energy use. Comerford, Lange, and Moro (2016), however, provide an interesting case study of the U.K. property's energy performance certificate (EPC), which requires that all homes that are put up for either sale or rent disclose energy costs on a 0-100 scale together with a letter ranking. They find that the introduction of EPC led to more investments in energy-efficient technologies, and thus support the idea that labels may help correct informational market failures. The work of Brounen and Kok (2011) on voluntary European EPCs suggests that energy information from the label is partly capitalized in the price of homes. However, if information from building energy labels is not fully understood, or some consumers dismiss this information, minimum standards can complement this type of policy to further correct for asymmetries of information in the building sector.

4. Expanding the Conversation: Supply-Side Market Failures

Firm decisions pertaining to investments in innovation, R&D spending, timing the introduction of innovations into the market, the menu of products (including attribute bundling), and prices are all levers by which firms strategically compete and can extract rents from consumers. Until now, cost-benefit analyses of minimum standards have largely ignored these market forces. Several recent research efforts, however, have uncovered puzzling phenomena that suggest that market power combined with innovation market failures interact with minimum standards.

First, there is clear evidence of consistent downward trends in the real prices of residential appliances. More importantly, there is a consistent pattern indicating that prices dropped precipitously, and in general began trending downward more quickly, when minimum standards were enacted or became more stringent. Figure 2, from Nadel (2002) referencing Schiellerup (2001), shows evidence of this effect in the U.K. when the European Union (E.U.) standard for refrigerators and freezers became effective in 1999. Figure 3 from Spurlock (2013) shows evidence that the within-model real prices of clothes washers dropped discretely, as well as began trending downward more quickly, at the time the 2004 and 2007 minimum energy efficiency standards for that product came into effect in the U.S. Additionally, Spurlock (2013) showed that the average real prices of clothes washers did not change significantly at this same time.[8] Considering a longer term perspective, Van Buskirk, Kantner, Gerke, and Chu (2014) show that, as a function of cumulative production (as motivated by the learning curve literature) the prices of several appliances in the U.S., as well as refrigerators in the Netherlands, have generally been trending downward as a function of cumulative shipments, and this trend appears to have accelerated at the time that the national minimum standards program started for these products. This pattern can be seen in Figure 4. They show that this pattern fits a functional form used in modeling learning-by-doing, and argue that standards may have spurred innovation in the manufacturing process that generates cost-efficiency and thus a decrease in prices. While these patterns may be consistent with learning and more broadly with technical change, causality is hard to establish as other factors might also be at play.

Spurlock (2013) along with Houde (2013), among others, suggest that these patterns are also consistent with firms engaging in strategic pricing and product differentiation. While the model of market power they emphasize is a static model of cross-sectional product price discrimination, it is worth noting that the downward within-model price trends observed in this industry are consistent with intertemporal price discrimination (products introduced at a high price and then discounted over time).

In sum, both market power and innovation market failures can rationalize the above puzzles. In the remainder of this section, we further expand on how each of these market failures can justify minimum standards. But we want to emphasize that the true challenge in evaluating the normative impact of

[8] Spurlock (2013) also shows that the broader long-term downward trend in real within-model prices is also present for clothes dryers and room air conditioners during the 2002-2008 period.

minimum standards lies in understanding how market failures operating on the demand side and supply side of the appliance market are fundamentally connected. For instance, if there is significant heterogeneity across consumers in the degree to which they pay attention to energy use (due to a subset of the population acting as principals while others act as agents for example), this enables firms to strategically segment customers, and allows them to exercise their market power. Moreover, in a dynamic context, firms might strategically withhold or delay cost-saving innovations from implementation to further exercise market power (e.g., Loury 1979; Karp and Perloff 1996; Kutsoati and Zabojnik 2005) and even influence the design of future regulations (Lyon and Maxwell 2008).

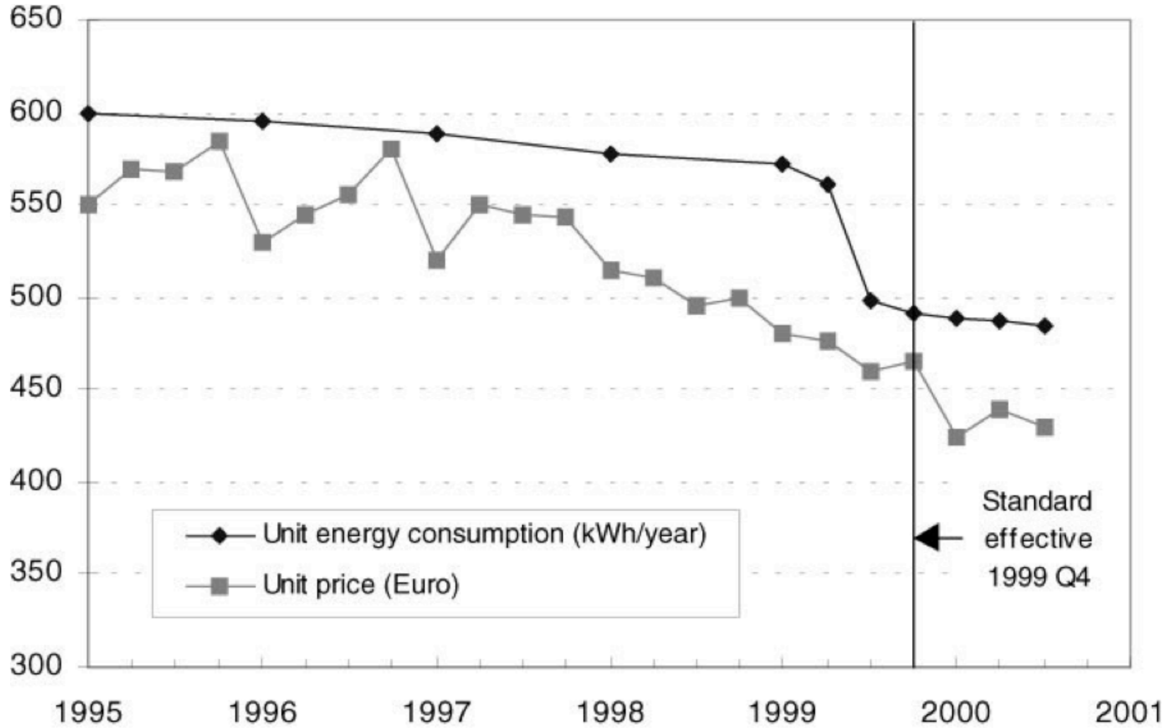

Figure 2. U.K. Refrigerator Prices
Source: Nadel (2002)

4.1. Market Power

The appliance market in the U.S. is moderately concentrated and is best characterized as an oligopoly with differentiated products. The 2006 merger of Whirlpool and Maytag, two of the four most prominent appliance manufacturers in the U.S., raised concerns that the market may have become overly concentrated and gave firms substantial market power. Ashenfelter, Hosken, and Weinberg (2013) show that following this merger, manufacturers did indeed exercise more market power, which led to higher prices in the most concentrated appliance categories. The existence of market power has important implications for minimum energy efficiency standards for appliances.

Several theoretical studies have investigated the more general question of whether imperfect competition can motivate minimum quality standards (MQS). The consensus from these studies tend to be yes, although the robustness of this conclusion depends somewhat on the nature of the competition between firms, heterogeneity and structure of firms' cost functions, and dynamic effects, among other factors. The model of Ronnen (1991), one of the first papers investigating MQS in an imperfect competition setting, provides most of the intuition for this result. He showed that a MQS can be welfare improving because they effectively limit firms' ability to differentiate their products. This, in turn, limits the ability of the firm to screen customers with heterogeneous preferences over the regulated quality dimension. As a result, firms can no longer charge an exaggerated premium for quality to customers with a high willingness to pay by suppressing quality targeted to customers with a low willingness to pay. The MQS forces up the quality provided to low willingness to pay customers, which reduces the profit maximizing price (previously inflated above the socially optimal level) of higher quality products. As a result, firms compete on a restricted product space--this increases competition and leads to lower (hedonic) prices.[9]

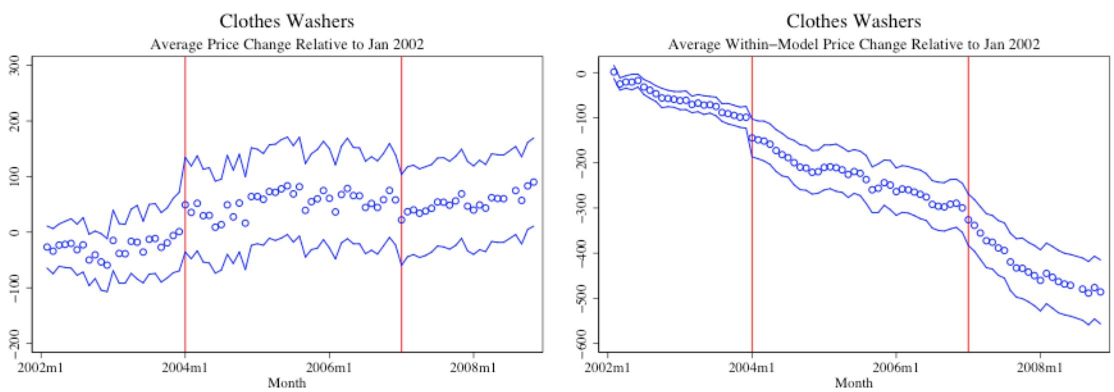

Figure 3. U.S. Clothes Washer Price Trends
Note: the left-hand panel shows the average real prices of clothes washers, while the right-hand panel shows the average within-model real price. The red line indicates the dates that the minimum energy efficiency standards changed for clothes washers. The vertical axis is in dollars, and, in the case of the right-hand panel, shows the average change in within-model price between any two periods over time for products existing in the market across that time step. Source: Spurlock (2013)

The empirical work on MQS in an imperfectly competitive market setting, on the other hand, is surprisingly limited. In the appliance market context in particular, we are aware of only a handful of papers investigating this topic. Spurlock (2013) studies the U.S. clothes washer market and focuses on how prices changed following the revision of minimum standards. She finds patterns consistent with a model in which firms price discriminate, and which can hardly be rationalized by a perfectly competitive market. In particular, she shows that the prices of mid-low efficiency products had a large decrease in level together with a downward break in trend exactly at the time more stringent standards became effective. She argues that, as is consistent with the predictions in Mussa and Rosen (1978) and Ronnen

[9] Several papers have extended Ronnen (1991)'s framework and show that these results tend to hold. For instance, Valletti (2000); Pezzino (2010); Toshimitsu and Jinji (2007) compare quantity to price competition. Ecchia and Lambertini (2001) investigates the role for firm heterogeneity. Crampes and Hollander (1995) assumes that quality is provided via a variable cost function instead of only fixed costs as in Ronnen (1991). Napel and Oldehaver (2011) investigates dynamic effects.

(1991), firms reduced the price of products at the efficiency level just above that eliminated by the new standard. This is the effect predicted by price discriminating firms who want to continue to serve customers previously targeted with the products that were eliminated by the standard. On the other hand, these prices would be expected to remain unchanged in a perfectly competitive market following this regulatory change.

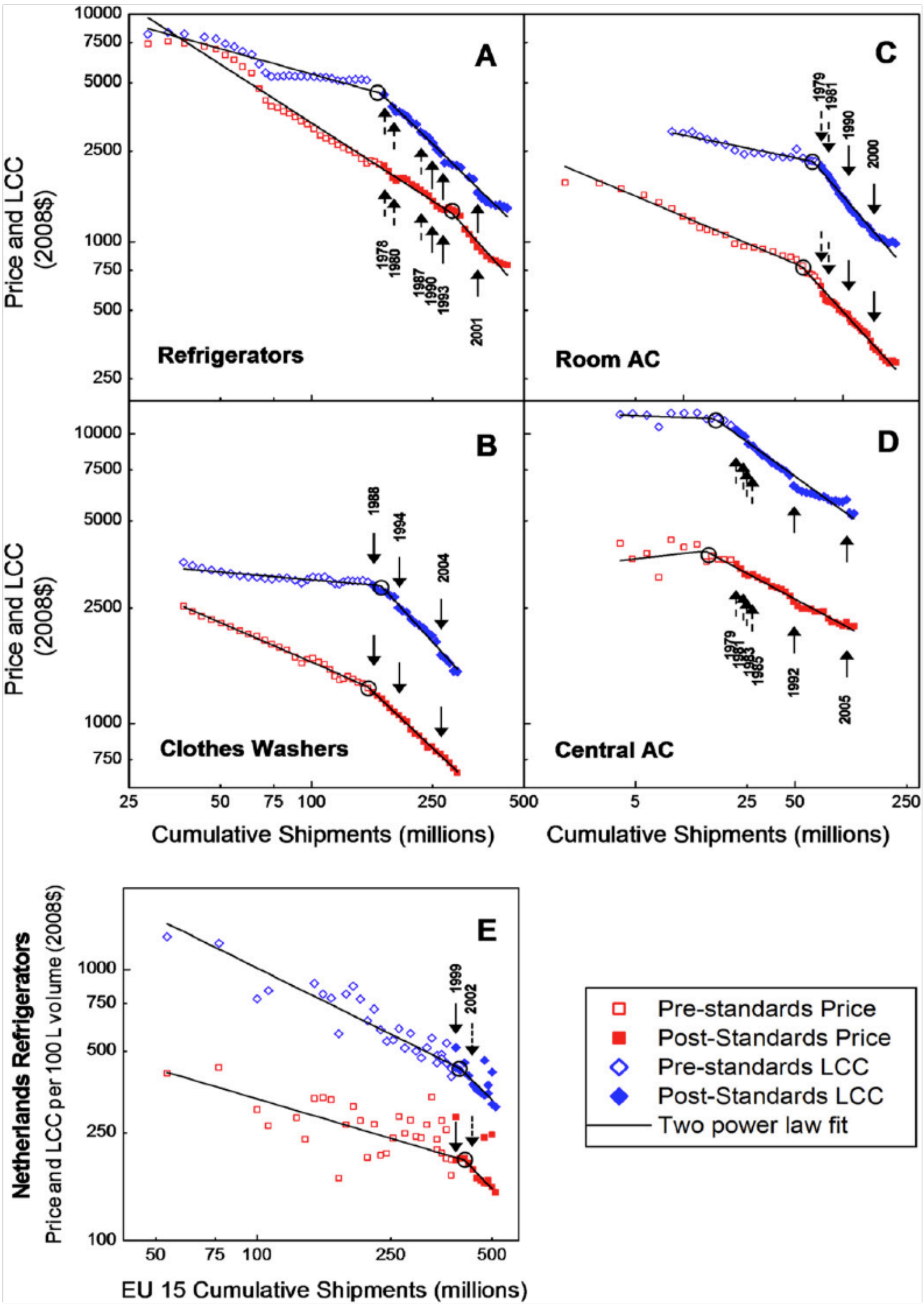

Figure 4. Long Term Prices as a Function of Cumulative Shipments
Source: Van Buskirk, Kantner, Gerke, and Chu (2014)

Houde and Spurlock (2015) expand the analysis of Spurlock (2013) to explore "quality decisions." They show that the price-adjusted quality of clothes washers as well as several other appliances (dishwashers, room air conditioners, freezers, compact refrigerators, and full-size refrigerators) increased following the revision of some appliance standards. Moreover, they show that the increase in quality is not entirely driven by an increase in energy efficiency. In particular, they show that more stringent appliance standards may have led manufacturers to increase appliance size and add more non-energy related features to their products. They argue that these patterns are consistent with manufacturers engaging in more product differentiation in dimensions of the product space not directly affected by the increasingly stringent standards. This result makes sense if the marginal cost of providing greater energy efficiency is upward sloping, and the restriction in the product space imposed by the new standard could more easily be relaxed in other quality dimensions. Brucal and Roberts (2015) also provide findings consistent with Spurlock (2013) and Houde and Spurlock (2015). They show that during the 2001 to 2011 period, the quality-adjusted price of clothes washers was subject to a strong downward trend during a time when this appliance category was subject to several standard revisions. The common belief is that more stringent standards should lead to the exact opposite effects, i.e., an increase in prices and reduction in quality. They also speculate that imperfect competition may have played a role in these patterns.

One challenge faced in the above studies is the establishment of a valid counterfactual to determine how standards affect market outcomes. The above studies take different approaches to overcoming this challenge. Brucal and Roberts (2015) rely solely on time series evidence for one appliance category, while Spurlock (2013) and Houde and Spurlock (2015) compare patterns across different appliance categories and exploit differences in the timing of the standard revisions. In this way, they are able to use appliances with no policy changes as counterfactuals for those that experienced revisions to their minimum energy efficiency standards.

In order to truly understand how minimum standards and imperfect competition interact, one would ideally like to compare a market with and without a minimum standard and subject to exogenous changes in the degree of (imperfect) competition. We are not aware of a study that has these two sources of variation. However, Cohen, Glachant, and M. Söderberg, Magnus (2015) are able to provide a counterfactual scenario that includes the latter, and Houde (2013) provides a counterfactual scenario that does the former. In particular, Cohen, Glachant, and M. Söderberg, Magnus (2015) investigate what would happen to market shares in the U.K. refrigerator market if appliance prices were set at their competitive level. They find that the market shares of the most efficient models (smaller size models in their context) would actually decrease under perfect competition. This suggests that market power enables firms to sell more energy efficiency models. This finding is consistent with Houde (2013) who shows that U.S. refrigerator manufacturers exploit the ENERGY STAR certification to second-degree price discriminate. If we were to remove the certification, firms would offer models that mostly just meet the minimum standard and markups would be much lower. One caveat from this study is that ENERGY STAR acts as a voluntary standard. Houde (2013) did not investigate the impact of changing a minimum standard in this context.

In sum, the theoretical models predict that minimum standards can increase competition, reduce the ability of firms to strategically price discriminate, and ultimately increase welfare. There is no empirical work of which we are aware that formally tests any of these models and their underlying assumptions. However, the results from the empirical work outlined above are a first step in this direction. Some of the patterns in the evolution of prices and quality of appliances are consistent with the response of an imperfectly competitive market to minimum energy efficiency standards. In particular, it appears to be the case that minimum energy efficiency standards for appliances have put downward pressure on prices, while quality has increased, and in more dimensions than only the regulated dimension.

4.2. Innovation Market Failures

Irrespective of firms' ability to exercise market power, innovation should also be an important driver of long-term trends in prices and quality. This in itself is not a rationale for policy intervention. But as long as private firms are likely to underinvest in R&D relative to the social optimum due to the positive externalities associated with increased knowledge (Jaffe, Newell and Stavins 2003; Spence 1984), there is a role for government regulations that can encourage an increase in R&D investment in innovation in a desired direction. For the present discussion, the question is then whether minimum standards create economically important positive externalities that further spur innovation.

Newell, Jaffe, and Stavins (1999) provide a useful framework and taxonomy for exploring the interaction between innovation and minimum energy efficiency standards for appliances. They study the effect of variation in energy prices, labeling requirements, and minimum energy efficiency standards on the rate and direction of technological change in the case of three appliances (room air conditioners, central air conditioners, and gas water heaters). They find evidence of underlying autonomous innovation, the rate of which is independent of energy prices, labeling, or regulation. However, they show that the direction of innovation (i.e., in this case towards more energy efficient technologies) is affected by energy prices as well as appliance standards. These results suggest that regulation can affect at least the direction of innovation in the regulated market. Popp (2002) also looks at innovation in the area of energy technologies with an emphasis on energy efficiency, and shows that the current stock of knowledge, as well as energy prices, has a strong positive effect on innovation activity and technological progress. Together with the findings of Newell, Jaffe, and Stavins (1999), this suggests that if appliance manufacturers were to innovate in a desired direction, the stock of knowledge in that direction would increase, thereby facilitating even more innovation in that direction in the future.

Aside from Newell, Jaffe, and Stavins (1999) and Popp (2002), there is little rigorous empirical investigation studying the role of regulation on innovation in the context of appliances. Some have explored this topic less formally; in the previous section we summarized the results of Houde and Spurlock (2015) and Brucal and Roberts (2015), both of which touch on this issue. In addition, Taylor, Spurlock, and Yang (2015) conduct a descriptive analysis exploring several questions related to the impact of regulation on appliance quality and prices over time. They find that in general the quality of all five of the appliances they analyze has increased across standard changes during the past several decades, and that there was a strong result of market prices below those projected by the standards rulemaking analyses for these products. All of these studies corroborate the general trend of downward pressure on prices and increasing quality, but do not formally distinguish between the role of market power and innovation market failures.

There is some compelling anecdotal evidence showing that significant product innovation beyond expectations has resulted from minimum efficiency standard regulation. For instance, Nadel (2002) describes such a case; during the 1989 rulemaking process for a new refrigerator standard, manufacturers claimed that the new standard would be too stringent for them to meet. However, once the standard was implemented, not only did refrigerators remain available and affordable, but many models were produced that exceeded the new standard by twenty percent. Taylor, Spurlock, and Yang (2015) also provide a similar anecdote; they point out that information from the manufacturers, documented during the analysis for the clothes washer standard changes effective in 2004 and 2007, indicated that top load clothes washers were not expected to be able to meet the new standard. It was assumed in the cost analysis that the industry would have to meet the standard by switching over to front-load washers entirely. However, this was clearly not what was observed in the market ex post. While the market share of front-load washers did increase substantially, as shown in Figure 5, top-load washers were in no way eliminated from the market during this time, and in fact regained more than fifty percent of the market share by around 2010. This suggests that there was substantial innovation with respect to the energy efficiency of the top-loading washer technology in order to meet this standard. Figure 6 shows the degree to which the distribution of top-load washer energy efficiency increased between 2003 and 2011 (recall that the new standard took effect in a two phase process in both 2004 and 2007). Over the same time period when all of this innovation was taking place, the average real prices of clothes washers did not change significantly (see Figure 3). Taken as a whole, the results from Taylor, Spurlock, and Yang (2015) suggest that innovation was likely at play in the industry response to minimum energy efficiency regulation. However, in order to generalize these results, much more needs to be understood about the mechanisms involved, as well as interaction with other factors (such as strategic pricing and product provision).

5. Conclusion

In this article, we have revisited the work of Hausman and Joskow (1982), who discussed the economic rationales for minimum energy efficiency standards for appliances at the time the policy was first being implemented at the federal level in the U.S. We have updated the discussion of the four market failures they highlighted as possible justifications for standards: energy prices below social marginal costs, consumers underestimating energy prices, consumer discount rates above social discount rates, and principal agent problems. We have argued that unlike following the 1970s energy crisis, when clearly U.S. subsidized energy prices were below market prices, current regulatory distortions may have the opposite effect. The argument that today's energy prices are below social marginal cost is less convincing and unlikely to be the main economic rationale for appliance standards. The question of whether consumers underestimate energy prices or have elevated discount rates above market returns are both cases with additional mixed results coming out of recent research, and no clear conclusion. However, we do note that there is evidence of heterogeneity in consumer discount rates, and allowing for this in future research is valuable in light of the interactions between the heterogeneity of consumer preferences for energy efficiency and the market power market failure we discuss.

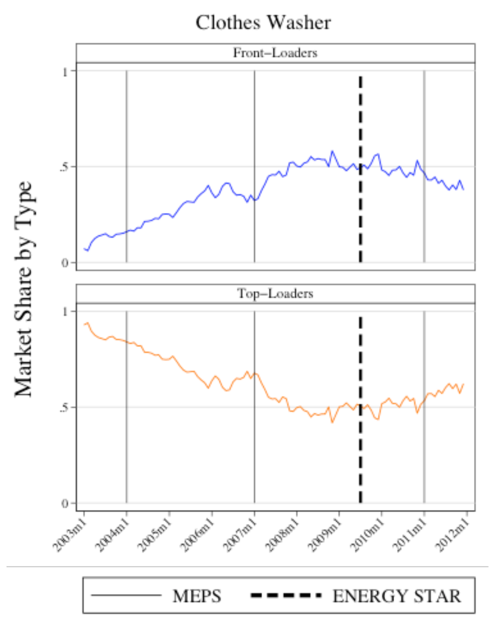

Figure 5. Product Type Market Share Trends

Note: market share trends by appliance type. MEPS refers to minimum efficiency performance standards. Source: Taylor, Spurlock, and Yang (2015).

Shifting the focus away from consumer perceptions or preferences alone, recent research suggests that market power and innovation are likely important factors that have normative implications for minimum energy efficiency appliance standards, particular when taken in combination. While minimum standards would not be the first-best policy for addressing any one of these supply-side market failures in isolation, in theory they can be a welfare improving policy intervention. We believe that a stronger case for minimum standards might be made by taking into account the interconnected and dynamic aspects of these supply-side market failures, together with their interaction with the demand-side market failures. However, much more needs to be understood about the economic magnitude and interaction of these market failures in a dynamic setting to understand the welfare implications of minimum standards in the U.S. appliance market.

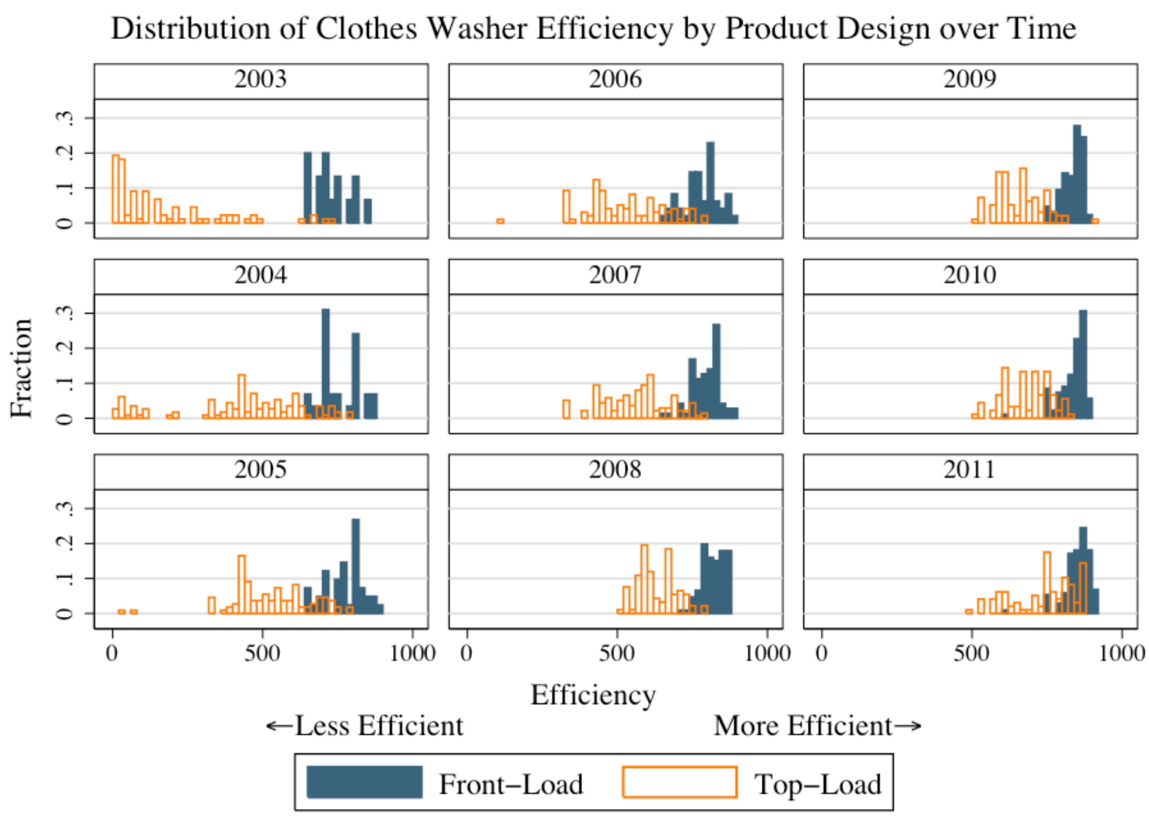

Figure 6. Product Type Efficiency Trends

Note: The distribution of efficiency across individual models by year and by front- and top-load clothes washers. Efficiency is defined as annual energy use minus 1000 (1000 was the largest observed annual energy consumption of any model in their data). The standard for clothes washers changed in January 2004 and then again in January 2007. Source: Taylor, Spurlock, and Yang (2015).

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